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(71) Applicant
Fronius Schweissmaschinen K.G. Austria

(Incorporated in Austria)

Gewerbestrasse 15-17, A-4600 Weis-Thalheim, Austria

(72) Inventors
Johann Kolar
Hans Ertl

(74) Agent and/or Address for Service
Baron & Warren
18 South End, Kensington, London, W8 5BU,
United Kingdom

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(54) **AC-DC converter for a D.C. voltage consumer and a method for supplying the consumer**

(57) In a converter 1 for a d.c. voltage consumer 2 supplied via a single or multi-phase a.c. voltage source 3, between the a.c. voltage source 3 and the d.c. voltage consumer 2 is arranged a rectifier 5 and an intermediate circuit 6 for controlling the voltage in the d.c. voltage consumer 2. The intermediate circuit 6 is associated with a control device 29. The control device 29 is connected at the input of the d.c. voltage consumer 2 with external voltage and/or current adjusting or monitoring devices. The output of the control device 29 is applied to a control input of a switching device 24. The switching device 24 is arranged between an electric energy store 26 and a magnetic energy store 19 and the intermediate circuit 6 is provided between the energy storage element 26 and the magnetic energy store 19. The switching device 24 may be a bipolar transistor (46, Fig 5), two devices (24, 56 Fig 6), GTO thyristors (97-99, Figs 12 and 16), IGBT (Figs 13, 14, 17 and 20). The d.c. voltage consumer 2 may be used for welding 33, 34.

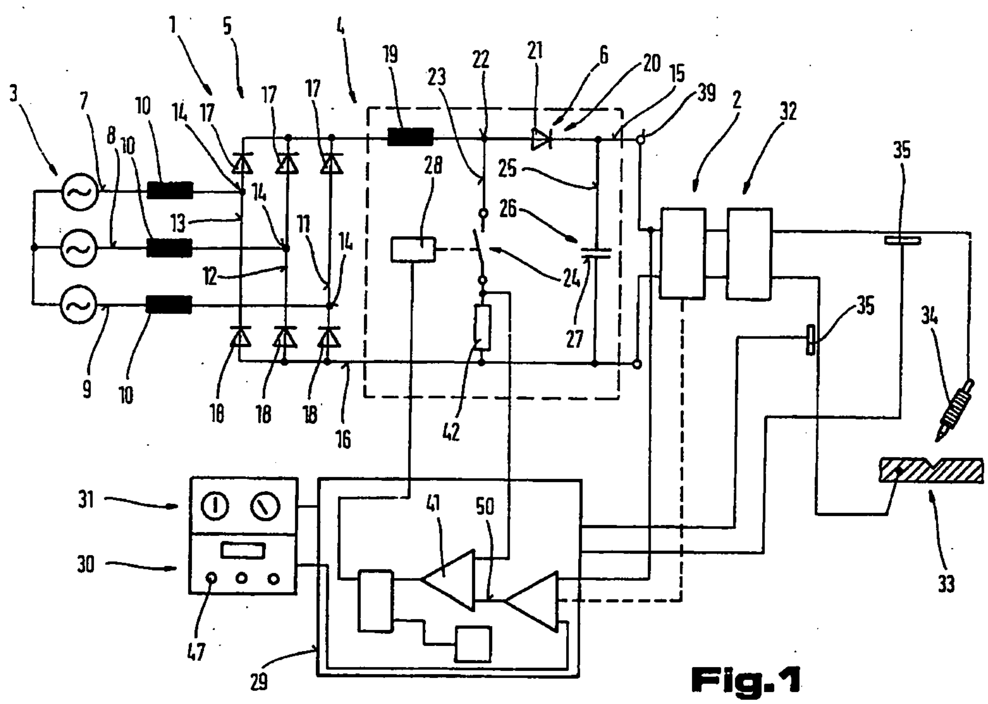

Fig.1

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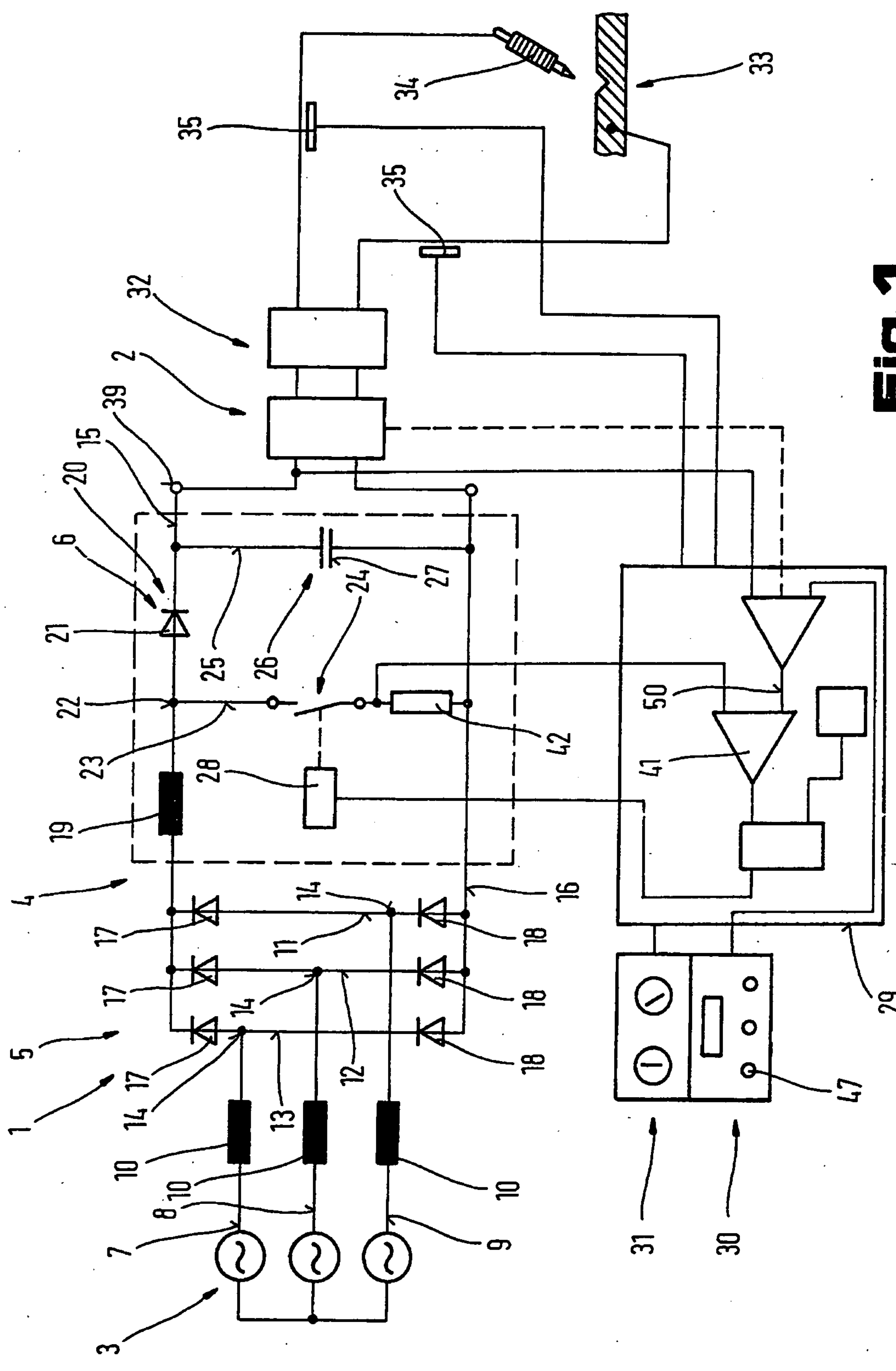
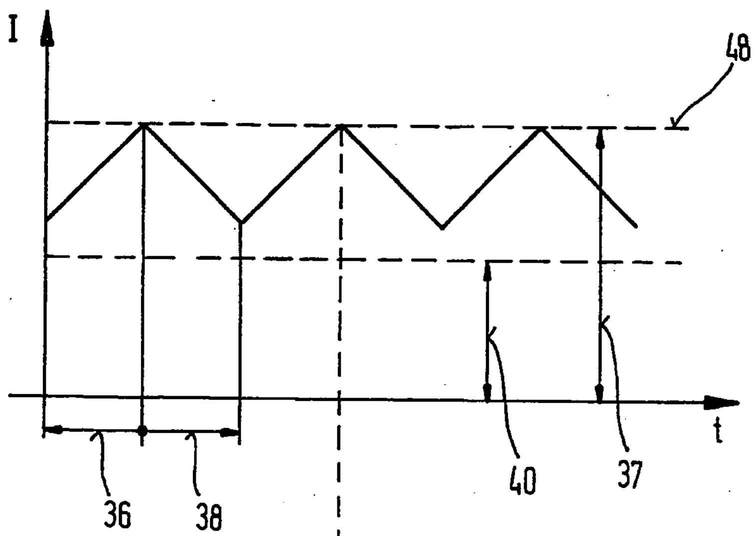


Fig.1

Fig.2



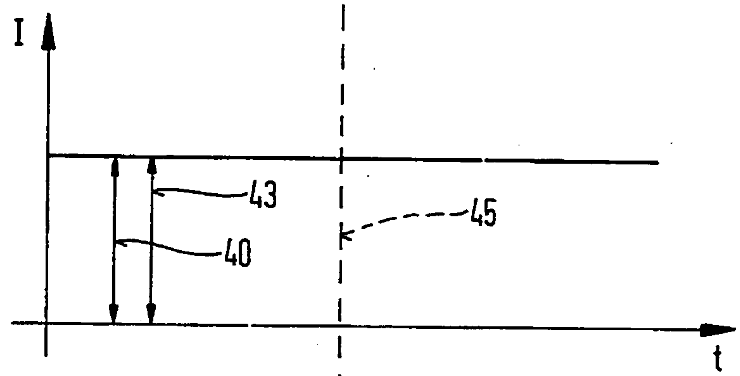


Fig.3

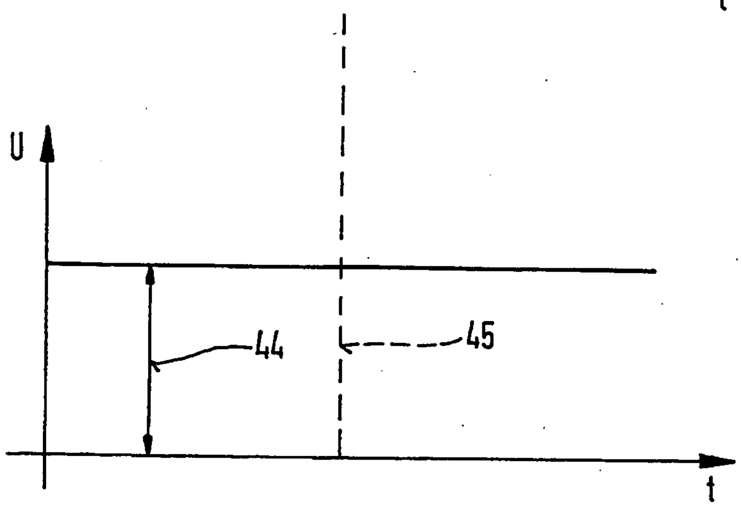


Fig.4

Fig. 5

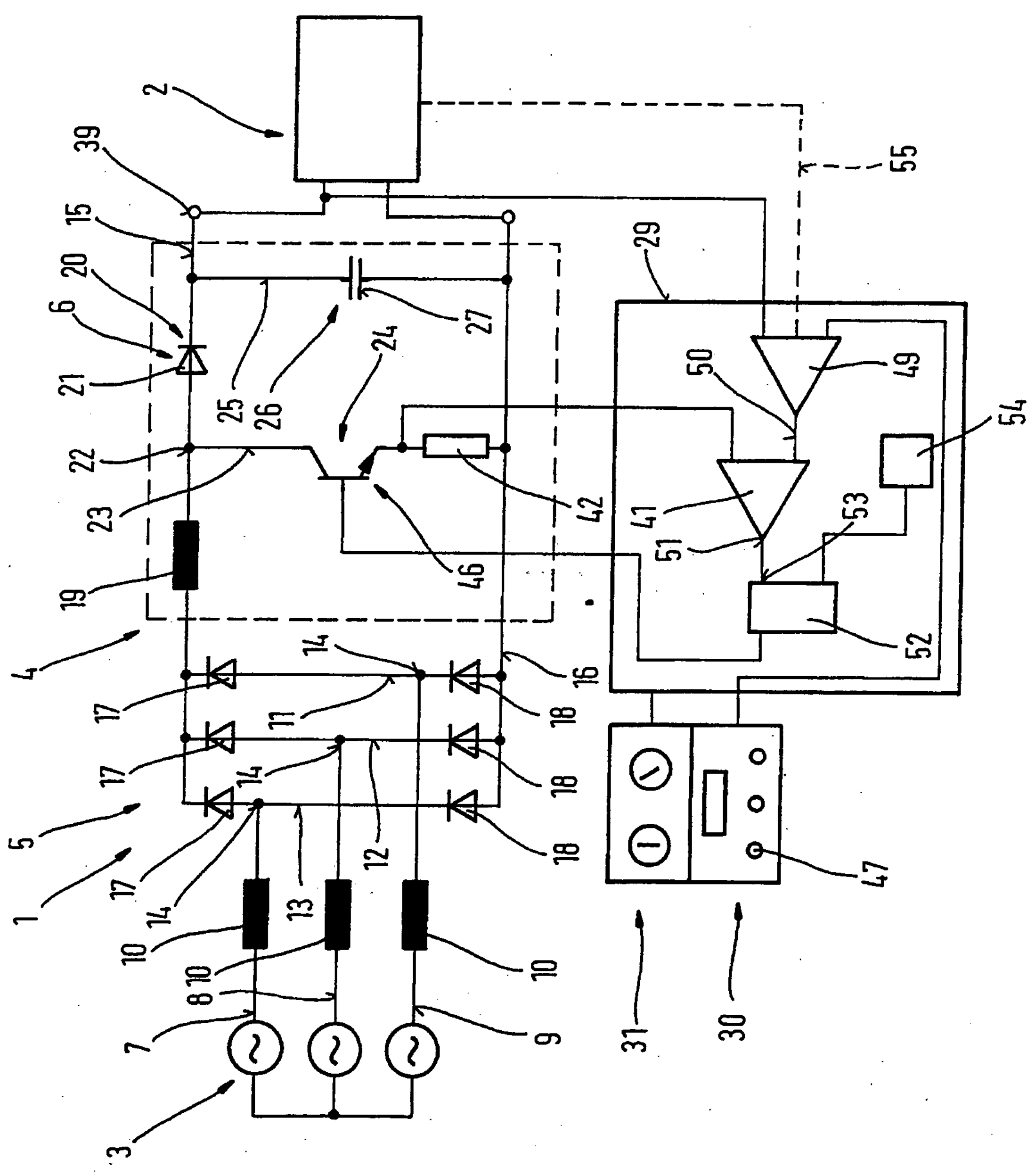

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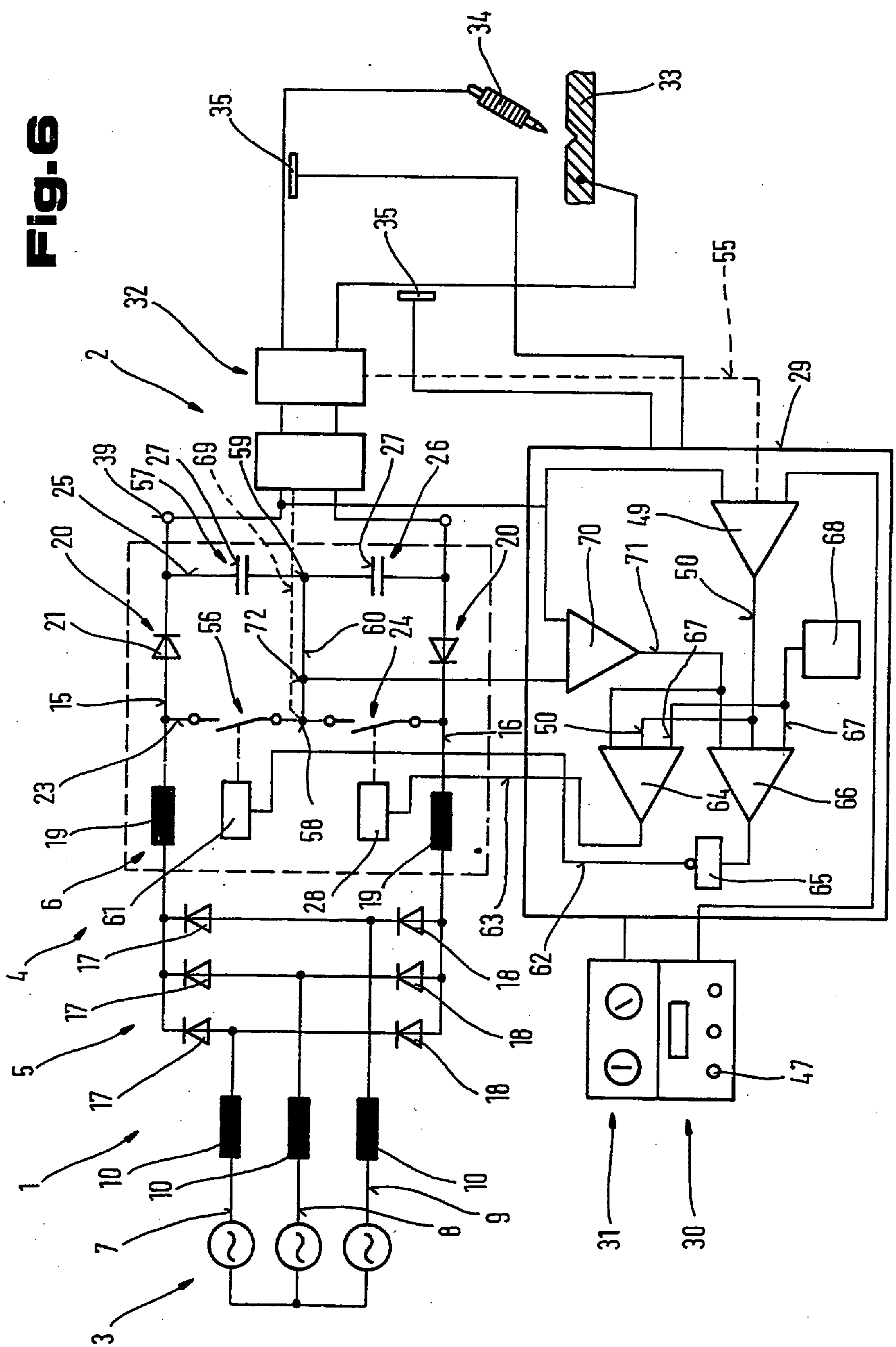
Fig.6



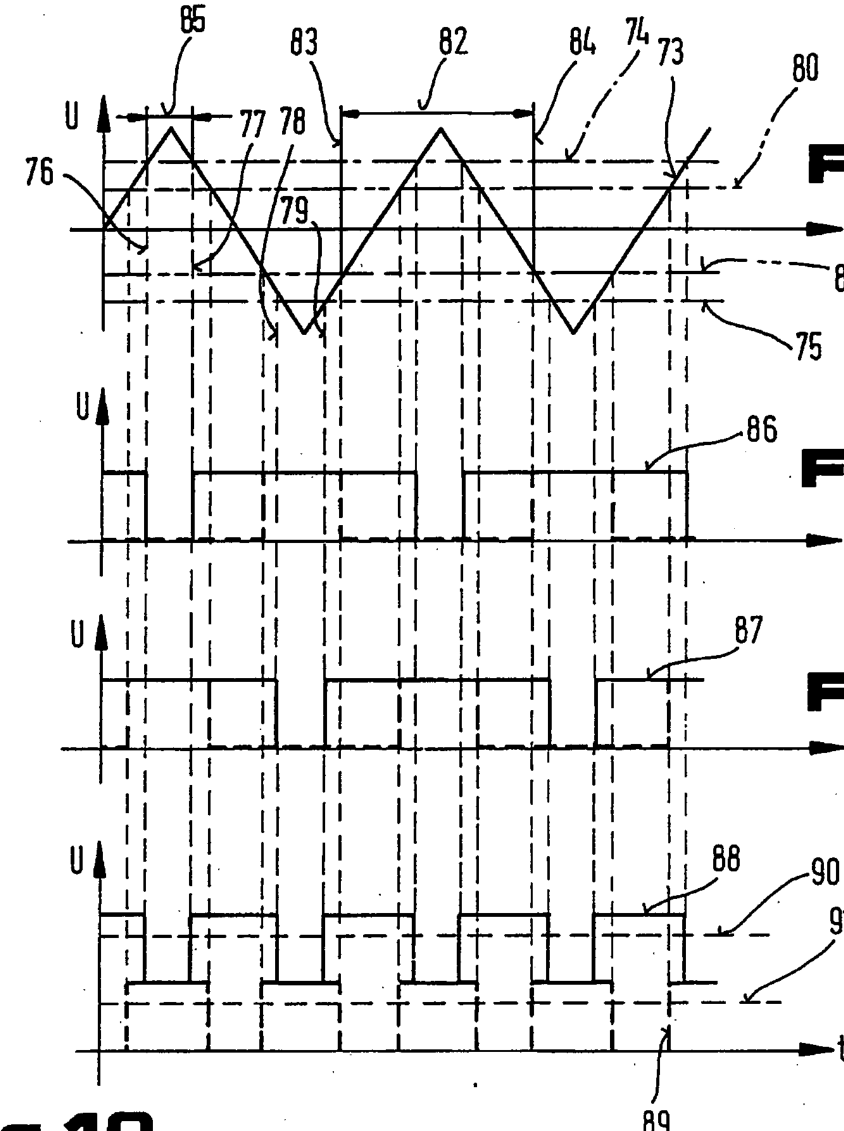


Fig.7

Fig.8

Fig.9

Fig.10

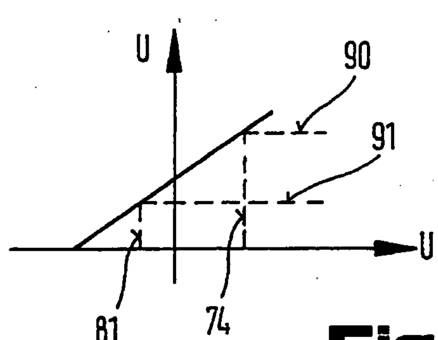


Fig.11

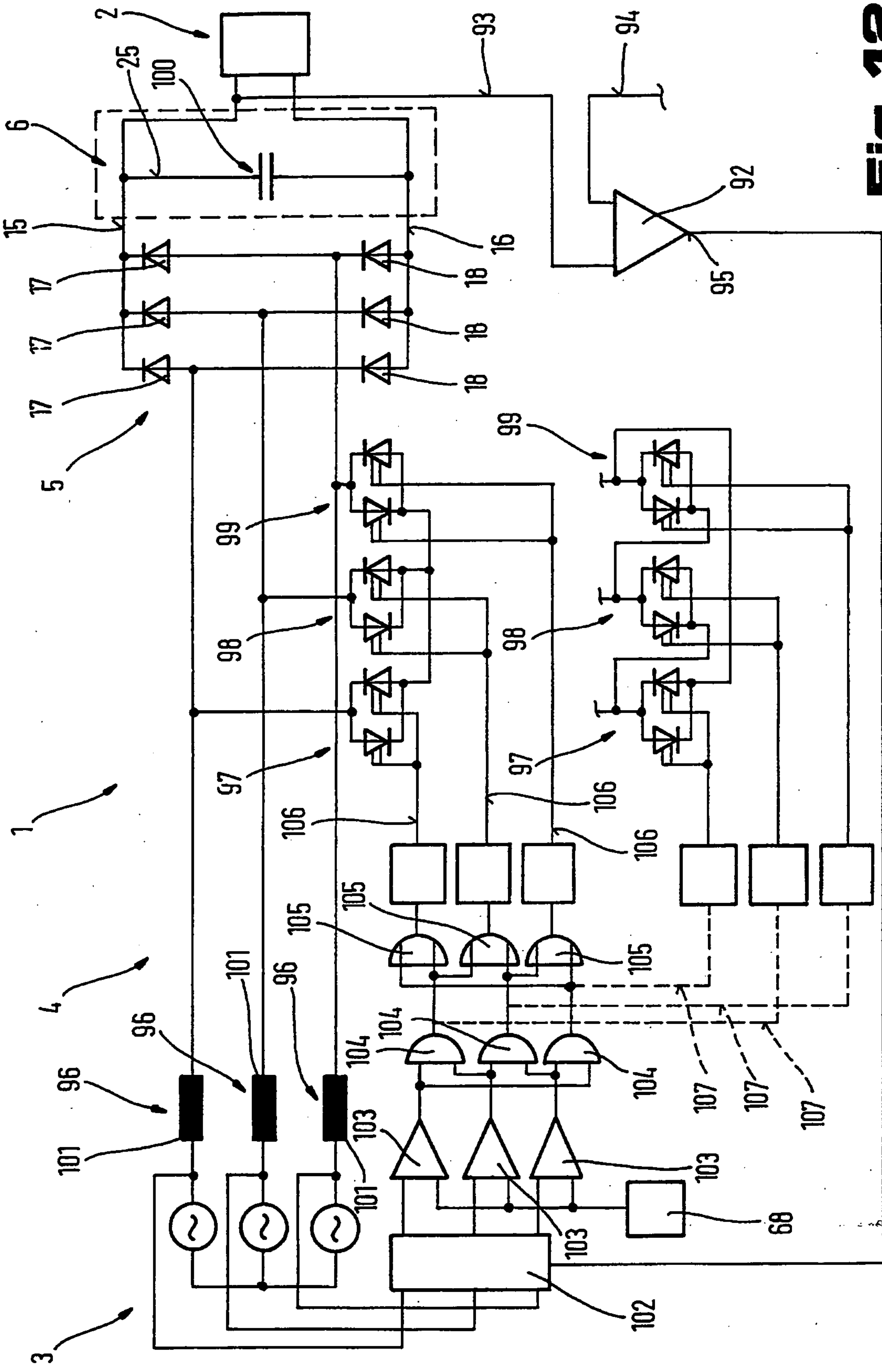

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Fig. 12

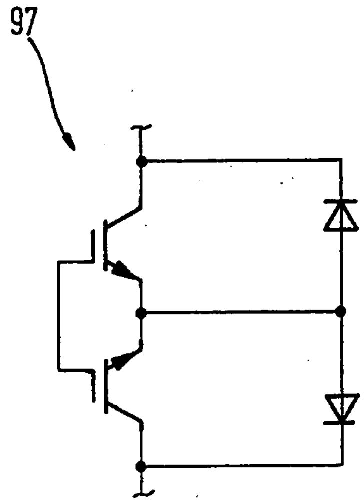

Fig. 13

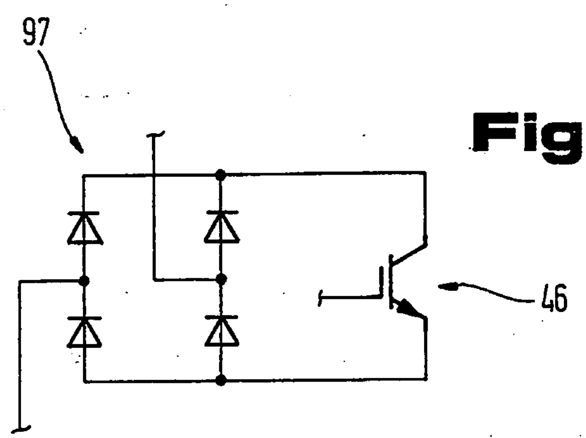

Fig. 14

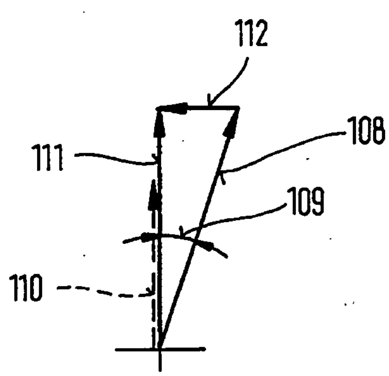

Fig. 15

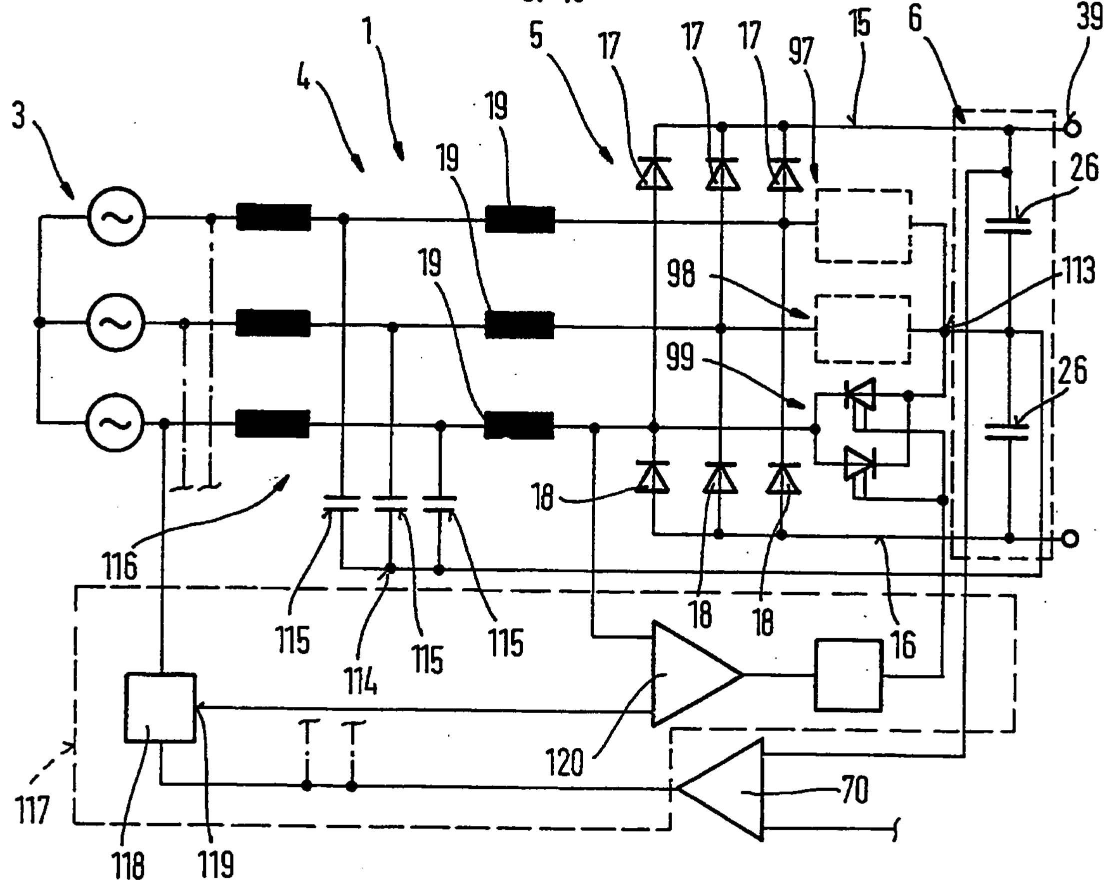

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Fig.16

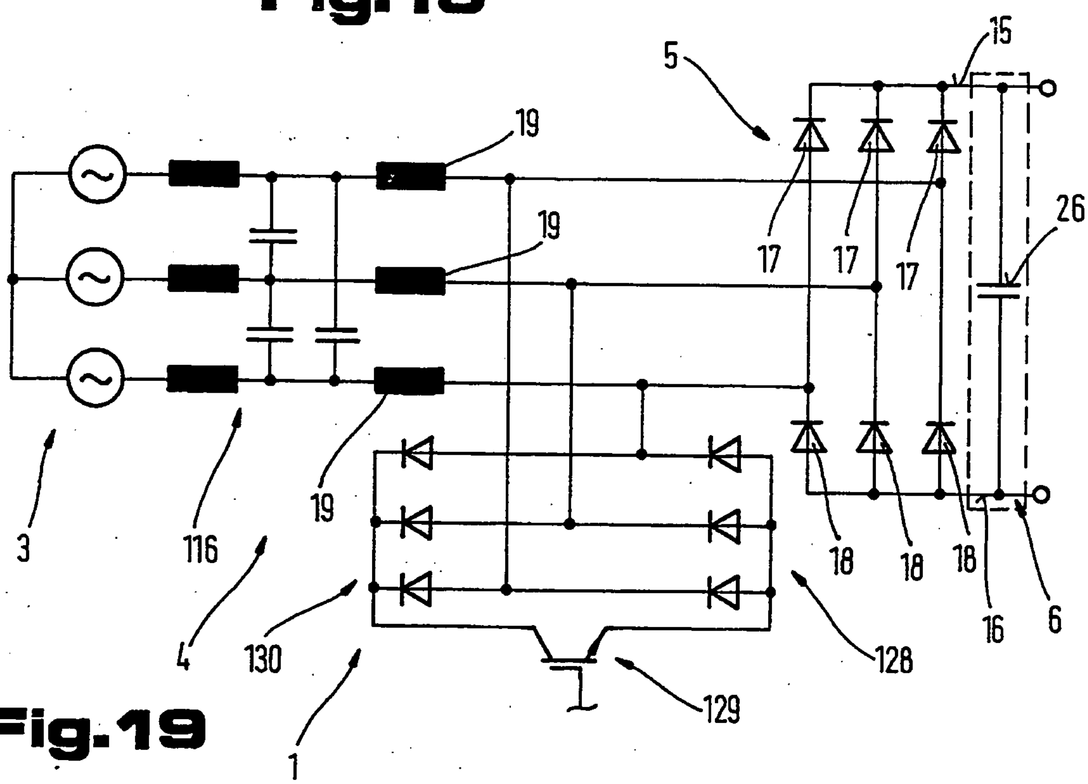

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Fig.19

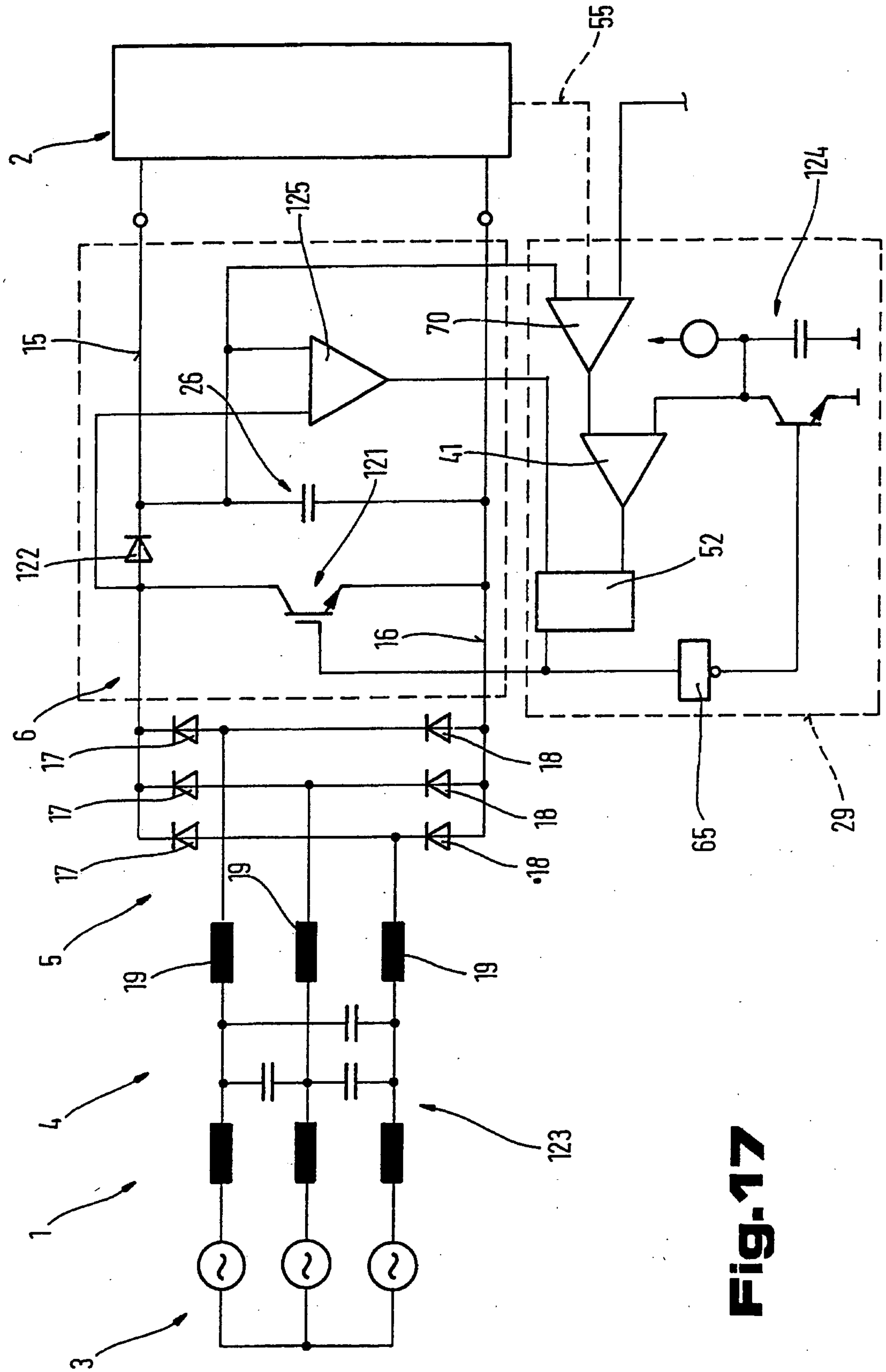

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Fig.17

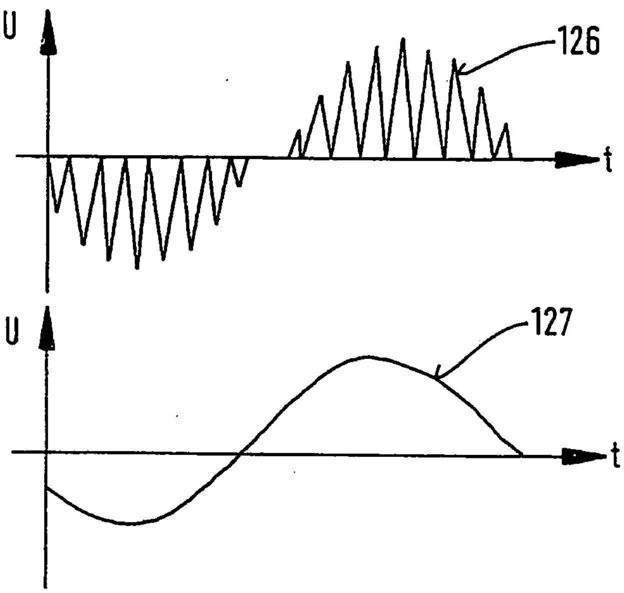
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Fig.18

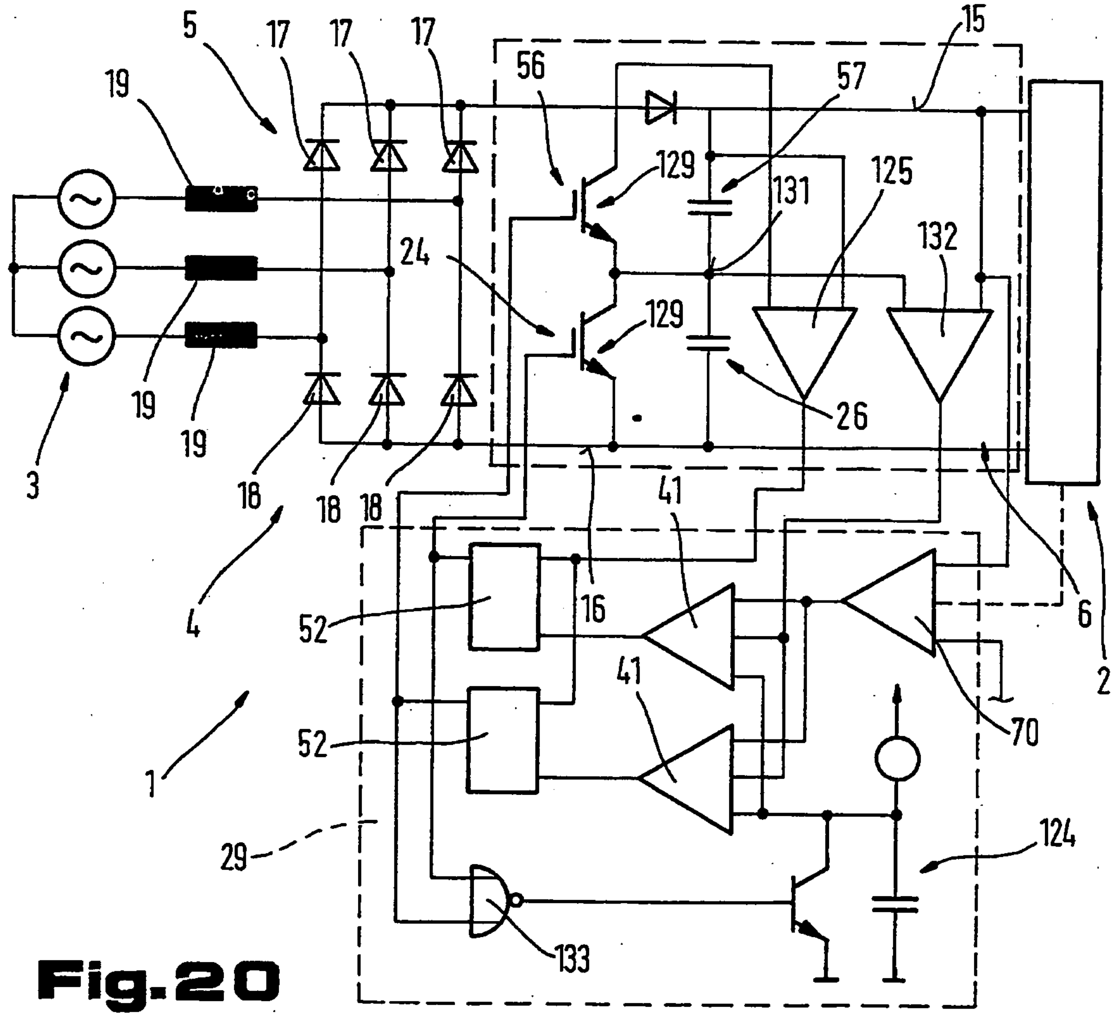
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Fig.20

VOLTAGE CONVERTER DEVICE FOR A D.C. VOLTAGE CONSUMER AND A METHOD FOR SUPPLYING THE CONSUMER

This invention relates to a voltage converter device for a d.c. voltage consumer supplied via a single or multi-phase a.c. voltage source. It also relates to a method for supplying a d.c. consumer with a constant, preadjustable voltage from an a.c. voltage source.

According to the state of the art, the simplest method of obtaining direct current from a single or three-phase a.c. voltage line is achieved by means of a diode-bridge circuit and subsequent smoothing. The essential limitations of this concept lie in the direct dependence of the intermediate circuit voltage on the a.c. mains voltage and the effects on the a.c. voltage line, especially the current harmonics resulting from the low current flow angle. Reselection or control of the output voltage is possible only by connecting in series a matching transformer and/or replacing the diodes by non-switching power semiconductors such as thyristors, as control can only be achieved through mechanical adjustment of the transfer ratio of the transformer or the change in the control angle of the thyristor bridge. The drawback in this case is the use of mechanical contacts because of servicing requirements, the high volume or weight of the arrangement, the low mechanical control dynamics and, especially during partial control of the a.c. mains current rectifier, the loading of the mains supply with current harmonics and control and commutation reactive power.

The object of the present invention is to develop an electronic power system and a control method by means of which it is possible to supply a d.c. consumer with a voltage which can be controlled independently of voltage swings or different nominal voltage levels of the three-phase network. Especially to be achieved is an increase in the current flow angle or furthermore an approximately sinusoidal mains current and less phase displacement

between the currents and voltages on the mains side.

According to one aspect of the invention, there is provided a voltage converter device for a d.c. voltage consumer supplied via a single or multi-phase a.c. voltage source including a voltage transformer arranged between the a.c. voltage source and the d.c. voltage consumer, a rectifier and an intermediate circuit for fixing the voltage at the d.c. voltage consumer, wherein the intermediate circuit is associated with a control device which is connected to external devices for adjusting or monitoring voltage and/or current at the input of the d.c. voltage consumer, and an output of the control device is applied to a control input of a switching device which is arranged between an electric energy storage element and a magnetic energy store, and the energy storage element and the magnetic energy store are provided between an output from the intermediate circuit and the a.c. voltage source, and at least the energy storage element or the magnetic energy store is arranged in the intermediate circuit.

The advantage of the solution achieved according to the invention can be seen by the combination of a one or multi-phase rectifier with these electronic power components, connected in series before or after as seen from the mains side, which make up the voltage converter device. This voltage converter device is made up of circuit switching power semiconductors, e.g. power transistors, diodes and electric and magnetic energy stores, and in conjunction with the rectifier this results in the structure of a three-phase a.c./ d.c. voltage step-up converter, i.e. a system which rectifies a given three-phase voltage input system and translates this into an output voltage level, lying above the peak value of the rectified main voltage, definable by a power semiconductor via a corresponding drive circuit. The basic function of the present step-up converter in general is the charging of a magnetic energy store from the three-phase mains via the power semiconductor controlled by the control commands and the partial or complete discharging of the energy store into the electric energy storage element thus boosting the d.c. voltage output voltage produced. At a given output power the size of the magnetic energy store or its inductive value is directly determined especially by the switching frequency of the power semiconductors,
which lies substantially above the main frequency, which advantageously results in a considerable reduction in volume, weight and therefore also cost of the voltage converter device. Furthermore, by using electronic power components the use of mechanical actuators is superfluous, as the control unit of such a device is electronically matched to different operating voltages or deviations in the operating voltage. A predetermined, constant d.c. supply voltage can thus be produced for supplying in a

preferred manner an electronic welding transformer. Apart from producing the output voltage, the control also has an effect on the mains current and, compared to known concepts, achieves a reduction in the harmonics and the reactive power load in the mains network.

Another variation of the embodiment is described in claim 2. The advantage in this solution is that the circuit for charging the magnetic energy store can be constructed in a simpler and operationally more reliable way and it is possible to suffice with only one operating device.

Advantageous also is an embodiment according to claim 3, as only one magnetic energy store suffices for the voltage converter device.

In an embodiment according to claim 4 the advantage is that by using a simple commonly used component, such as for example a diode or a switch, it is possible to divide the intermediate circuit into two parts for charging the magnetic energy store and for supplying the d.c. voltage consumer from the electric energy storage element.

Another embodiment is described in claim 5, according to which it is possible to achieve a contact-free interruption or splitting of the intermediate circuit into halves.

Another variation of the embodiment is described in claim 6. The advantage in this case is that the cut-off voltage requirement of the switching devices, especially when using power semiconductors, can be halved whilst the effective switching frequency is doubled. The control of the voltage of the capacitive junction in the d.c. voltage consumer can then be included in the control of the intermediate circuit voltage.

The embodiment according to claim 7 enables the supplied energy to be stored in two parallel connected magnetic energy stores in the supply lines between the rectifier and the switching devices.

However, an embodiment according to claim 8 is also possible according to which the harmonic load can be reduced in the a.c. voltage mains network.

The embodiment according to claim 9 on the other hand ensures that through the magnetic energy store arranged in the a.c. voltage network the harmonics are dampened at the same time and additional damping methods are therefore superfluous.

The variations of the embodiment according to the claims 10 and 11 enable the circuit of the voltage converter device to be simply matched to different load situations in the d.c. voltage consumer.

The advantage in the solution according to claim 12 is that short periods of ON load take place in the individual phases which prevent the mains net from collapsing but which otherwise makes it possible for the other phase or the other phases to stabilise again while one of the phases is under load.

The embodiment according to claim 13 enables the unrestricted control of the voltage in the area of the d.c. voltage consumer.

Also advantageous is an embodiment according to claim 14, as this allows the use of contact-free switches so that higher powers can be switched through the switching devices without requiring oversize cooling plant or the like.

Advantageous is also an embodiment according to claim 15, as this achieves a simple control of the switching device which is cost effective and can be supplied in large numbers.

For smaller power ratings is recommended the embodiment according to claim 16.

In the embodiment variant according to claim 17 the smaller size magnetic energy stores suffice because they are spread over several phases of the a.c. voltage consumer and despite this a control with only one switching device is possible.

According to another aspect of the invention, there is provided a method for supplying a d.c. voltage consumer with a constant, preadjustable voltage from an a.c. voltage source, in which the a.c. voltage is rectified and the d.c. voltage is kept at a preadjusted value in an intermediate circuit, wherein the intermediate circuit is applied to the a.c. voltage source at timed intervals in successive periods of varying time and between these periods the energy supplied from the a.c. voltage source is stored in an energy storage element or an inductance, and during the period the energy taken up by the inductance or the energy storage element, charged from supply voltage of the a.c. voltage source, is supplied as the operating voltage to the d.c. voltage consumer.

Of advantage in this case is the fact that non-symmetrical mains loads or harmonic oscillations can largely be prevented.

Proceeding according to claim 19 is advantageous to the extent that the operating voltage can be fixed in a simple manner by designing the magnetic energy store in conjunction with the electric energy storage element.

The advantage in proceeding according to patent 20 is that the energy which is required by the d.c. consumer can be very quickly adapted to the different requirements.

Finally, a procedure according to claim 21 is also possible according to which by a simple conversion or change-over of the operating voltage at the d.c. voltage consumer it is possible to achieve the operating voltage at the a.c. voltage source.

The invention will be described further, by way of example, with reference to the accompanying drawings, in which:-

Fig. 1 shows a circuit diagram of a device according to one embodiment of the invention for the voltage and current supply of a d.c. voltage consumer supplied from an a.c. voltage source;

Fig. 2 shows a diagram of the current flow in the magnetic energy store of an intermediate circuit shown in Fig. 1;

Fig. 3 shows a diagram of the current flow for the d.c. voltage consumer;

Fig. 4 shows a diagram of the voltage at the input to the d.c. voltage consumer;

Fig. 5 shows a circuit diagram according to another embodiment of the invention including a switching device formed by a power semiconductor and a block diagram of the associated control;

Fig. 6 shows a circuit diagram of yet another embodiment of the invention including a voltage transformer with two series connected switching devices;

Fig. 7 shows a diagram of the voltage shape at the input of a comparator connected to a delta generator, as shown in Fig. 6;

Fig. 8 shows a diagram of the voltage shape in the area of one of the two switching devices of the voltage transformer according to Fig. 6;

Fig. 9 shows a diagram of the voltage shape in the area of a further switching device of the voltage transformer

according to Fig. 6;

Fig. 10 shows a diagram of the voltage shape at the junction of the two switching devices;

Fig. 11 shows a diagram of a control characteristic of the voltage shape in the intermediate circuit;

Fig. 12 shows a circuit diagram of another embodiment according to the invention in which the switching devices are arranged in the a.c. voltage circuit;

Fig. 13 shows a further modification of the invention;

Fig. 14 shows yet another modification of the invention;

Fig. 15 shows a vector diagram for voltage and current shape in the area of the a.c. voltage network;

Fig. 16 shows a still further embodiment in which the magnetic energy store and the switching device are arranged in the area of the a.c. voltage mains;

Fig. 17 shows another embodiment in which the magnetic energy store is arranged in the a.c. voltage network and the switching device is arranged in the intermediate circuit;

Fig. 18 shows a diagram of the current and voltage shape during the charging process of the magnetic energy store;

Fig. 19 shows a further embodiment according to the invention with magnetic energy stores and ____________________

switching devices arranged in the a.c. voltage network; and

Fig. 20 shows a circuit diagram of a different variation of an embodiment of a voltage transformer shown in Fig. 17 with two switching devices connected in series.

In Fig. 1 is shown a voltage converter device 1 for supplying a d.c. voltage consumer 2 from an a.c. voltage source 3. In order to ensure a constant supply voltage to the d.c. voltage consumer 2 independently of the voltage of the a.c. voltage source 3 and also for supplying a desired current for the d.c. voltage consumer 2, a voltage transformer 4 is arranged between the d.c. voltage consumer 2 and the a.c. voltage source 3. This voltage transformer 4 comprises a d.c. voltage rectifier 5 and an intermediate circuit 6 between the rectifier 5 and the d.c. voltage consumer 2.

The rectifier 5 may preferably be in the form of a diode rectifier as in the present embodiment, in which in the design of the a.c. voltage source 3 as a polyphase supply, each of the harmonics appearing in the phase lines 7, 8, 9, which could have negative effects on the a.c. voltage source 3, preferably with inductances 10 connected in between for limiting the harmonics appearing via the switching parts in the rectifier 5 or the intermediate circuit 6, are connected at junctions 14 to the lines 11, 12, 13. Diodes 17, 18, conducting in the same direction, are arranged in these lines 11, 12, 13 between the junctions 14 and a supply line 15 with positive potential and a supply line 16 with negative potential. In the present embodiment, the supply lines 15, 16 feed the intermediate circuit 6 of the voltage transformer 4 by connecting in series in the supply line 15 to the d.c. voltage consumer 2 a magnetic energy store 19 and a switching element 20. The switching element 20 can preferably be a diode 21 connected so as to conduct in the

flow direction.

Via a junction 22 between the magnetic energy store 19 and the switching element 20 is provided a connecting line 23 to the supply line 16 in which is arranged a switching device 24. In a connecting line 25, running parallel to this connecting line 23, between the supply lines 15 and 16 is provided an energy storage element 26 or a capacitor 27.

For controlling the drive 28 for the switching device 24 is provided a control device 29, which is schematically represented by a box and whose layout is explained later in more detail with the aid of a block diagram. This control device 29 is equipped with input devices 30 and display devices 31 for current and voltage in the various parts of the device and with these input devices 30 it is also possible to display the corresponding current and voltage values in the intermediate circuit 6 or at the d.c. voltage consumer 2.

This d.c. voltage consumer 2 for example can be used as a welding current source 32 for different welding processes, especially MIG/MAG or TIG, WIG or the like, such as for example electron beam welding and the like.

In this case for example the supply line 16 is connected to a workpiece 33 and the supply line 15 is connected to a welding torch or gun 34. The measuring values obtained in the area of the welding current source 32 can also be supplied to the sensor 35 in the intermediate circuit 6 or in the connecting lines 23, 25 to the d.c. voltage consumer 2 and to the control device 29.

In Fig. 2 is shown a diagram which represents the timing of the direct current flow. In this diagram the abscissa line represents the time (t) and the ordinate line represents

the current (I).

The operation of the voltage converter device 1 is now explained in more detail with the aid of Fig. 1 and 2.

The mains voltage rectified by the three-phase rectifier 5 when the switching device 24 is closed charges the magnetic energy store 19 via a time interval 36 to a value 37 of the current. After opening of the switching device 24 the energy stored in the magnetic energy store 19 is supplied via a diode 21 to the energy storage element 26 through a time length 38 which leads to a partial discharge of the stored energy. The intermediate circuit voltage at junction 39 is boosted by the electric energy storage element 26, which is in the form of a capacitor 27 and, in order to retain full controllability of the system, is preferably above the peak value of the rectified main voltage.

The intermediate circuit voltage is now stabilised by means of a double loop control in such a way that from the subtraction of the desired value given via the input device 30 and the actual value of the intermediate circuit voltage at the junction 39 a peak current appearing in the magnetic energy store 19 or the switching device 24 and thus also the signal with a height 40 for determining the average value of the intermediate current circuit is produced at the junction 39 and supplied to a comparator 41. This compares the instantaneous current in the switching device 24, determined for example by the voltage drop in a measuring resistance 42, with the value 37 of the intermediate circuit current, which forms a switching threshold, and activates the drive 28 which opens the switching device 24. By opening the switching device 24 the magnetic energy store 19 is discharged in the time length 38 via the diode 21 and charges up the electric energy storage element 26, i.e. for example the capacitor 27.

In this phase the d.c. voltage consumer 2 is supplied with energy from the magnetic energy store 19. If the energy output is greater than the energy required for the voltage defined by the capacitor 27 at the current pick-up and at the d.c. voltage consumer 2, the surplus energy is supplied to the electric energy storage element 26. After expiry of the predetermined time length 38 the switching device 24 is closed by the drive 28 via the control device 29, and the magnetic energy store 19 in turn is charged to the value 37 with the energy supplied by the a.c. voltage source 3.

During this time interval 36 for charging the magnetic energy store 19, the d.c. voltage consumer 2 is supplied via the connecting line 25 and the supply line 15 with the energy stored in the electrical energy storage element 26. With the correct choice of components and the time interval 36 or the time length 38 are chosen correctly, the energy stored in the electrical energy storage element 26 will be sufficient to supply during the time interval 36 the energy required by the d.c. voltage consumer 2.

After expiry of the time interval 36, the switching device 24 is opened and the aforementioned sequence is repeated.

In Figs. 3 and 4 is shown a diagram illustrating the current (I)and voltage (U)characteristics at the input of the d.c. voltage consumer 2 over the time (t). This illustration shows that the current shape at the output of the magnetic energy store 19 represented by full lines in Fig. 2 corresponds to a current value 43 of height 40, shown by full lines in Fig. 3 and 4, and to which a voltage value 44 is applied. The voltage value 43 is applied to the d.c. voltage consumer 2 starting from the instant 45 and the voltage is stabilised by the energy storage element 26.

In Fig. 5 is shown an alternative embodiment of the

circuit of the voltage converter device 1 shown in Fig. 1. As a variation of the embodiment in Fig. 1 the switching device 24 is replaced by a unipolar, unidirectional power semiconductor or transistor 46 which can be switched off. This power semiconductor 46 permits a blocking voltage and the current flow in one direction only. In contrast to the embodiment described in Fig. 1 this results in a contact-free switching process.

Also shown in this embodiment is a block diagram of the control device 29 for controlling this power semiconductor 46.

Stabilisation of the voltage in the intermediate circuit of the d.c. voltage consumer 2 is now effected in a double-loop control in such a way that from the subtraction of a desired value of the voltage adjusted by means of an adjusting member 47 at the input device 30 and an actual value of the voltage, which is tapped at the junction 39 of the intermediate circuit 6, for determining a peak value of the current appearing in the magnetic energy store 19 or the power semiconductor 46 and thus also for determining the mean value of the current in the d.c. voltage consumer 2 there is produced a signal 48 - in Fig. 2 shown as a broken line - which is applied to the output of a control amplifier 49. The output of the control amplifier 49 is applied via a line 50 to the comparator 41. This compares the momentary value of the current in the power semiconductor 46, for example obtained by the voltage drop in the measuring resistance 42, with a switching threshold which is formed by the signal 48 - in Fig. 2.

After reaching the switching threshold, a switching state memory 52 is addressed via the output 51 of the comparator 41. After the comparator 41 has been applied to the input 53 of the switching state memory 52, n receiving an output signal from the comparator 41 this switching state mem ry

52 is reset, thereby interrupting the connection via the power semiconductor 46. The switching-on of the switching state memory 52 for producing a line connection through the power semiconductor 46 throughout takes place via a clock generator 54 at the end of a given clock time. The switching threshold according to signal 48 is thus fixed in a steady-state via the current control circuit of the intermediate circuit 6, which is superimposed on the current control, in such a way that the power flow in the intermediate circuit 6 corresponds to the power consumption by the d.c. voltage consumer 2 at the voltage rate predetermined by the input unit 30.

It is also possible within the scope of the invention, either alternatively or simultaneously, to connect the control amplifier 49 directly to the d.c. voltage consumer 2 via a line 55 shown in broken lines. The load condition of the d.c. voltage consumer 2 being supplied can thus also be included in the control of the intermediate circuit 6.

If in the voltage converter devices 1 described in Figs. 1 and 5 no inductances 10 are connected on the mains side, the current is thus formed into current blocks displaced ideally by 120° according to the operation of the rectifier 5. By means of the inductances 10 it is possible, partly by the internal inductance of the non-ideal mains, to obtain from the rectifier 5 approximately trapezoidal shaped mains currents as a result of the greater overlap or slower commutation of the rectifiers. Through suitable dimensioning it is thus possible to achieve a reduction in the mains current harmonics.

The supply unit according to the invention can be expanded especially for high intermediate circuit voltages, such as shown in Fig. 4.

Th embodiment of the v ltage converter device 1

according to the invention shown in Fig. 6 differs from that shown in Fig. 1 by the fact that in the connecting lines 23 and 25 two switching devices 24, 56 and energy storage elements 26, 57 are connected in series respectively. Via junctions 58, 59 the connecting lines 23, 25 are connected between the switching devices 24, 56 and the energy storage elements 26, 57 via an intermediate line 60. In addition to the switching element 20 in the supply line 15, a further switching element 20 is also arranged in the supply line 16 between the junctions of the connecting lines 23 and 25 in the flow direction of the supply line 16.

If power semiconductors or transisters 46 are used for the two switching device 24,56, as described with the aid of the embodiment in Fig. 5, the blocking voltage stress can be reduced to half the maximum value of the voltage in the intermediate circuit 6. Furthermore, as a result of the arrangement of the series connected switching devices 24, 56 the switching frequency can be doubled and the control of the voltage of the capacitive intermediate circuit voltage centre point, i.e. the junction 59, can be included in the control of the intermediate circuit voltage. In this arrangement the magnetic energy store 19 can also be divided between the positive and negative voltage rail of the intermediate circuit.

The control of the drives 28 and 61 of the switching devices 24 and 56 takes place via the lines 62 and 63. The line 63 is applied to the output of a comparator 64 and the line 62 through the intermediary of an inverter 65 is applied to an output of a comparator 66. Applied to the comparators 64, 66 via lines 50 is an output of the control amplifier 49 which, as already explained with the aid of the circuit in Fig. 5, compares the difference between a desired voltage produced by the adjusting member 47 f the input device 30 and an actual voltage picked up at

junction 39 in the intermediate circuit 6. The control amplifier 49 may be additionally c nnected via the line 55 to the d.c. voltage consumer 2.

To the inputs of the comparators 64 and 66, apart from the lines 50, are applied lines 67 which connect a delta generator 68 to the inputs of the comparators 64 and 66. Through the differential measuring values of the control amplifier 49, which are supplied via the lines 50, the drives 28 and 61 are sooner or later activated, i.e. the electric energy storage elements 26 and 57 are charged for longer or shorter periods, in which at the same time the magnetic energy store 19 is charged up for longer or shorter periods and can thus store energy at a higher or lower rate.

Furthermore, as indicated by broken lines, any necessary balancing of the capacitor voltages in the capacitors 27, which form the electrical energy storage elements 26 and 57, can be achieved via a line 69 for the control of the voltage in the intermediate circuit 6 when the junction 58 is under load from the d.c. voltage consumer 2 connected in series with it.

The delta signal, which is supplied from the delta generator 68 to the comparators 64 and 66, is thus changed. In addition to this, in a control amplifier 70 is determined the difference between the voltage in the intermediate circuit 6 and at the junction 58 and this differential signal is supplied via a line 71 to the inputs of the comparators 64 and 66. This addition of the differential value determined, which is supplied via the lines 71 to the comparators 64 and 66, results in a corresponding displacement of the switching periods of the switching devices 24 and 56. Accordingly, the neutral point charging current applied t a junction 72 therefore has a balancing-out mean value which becom s zero only through

the even splitting of the voltage by the capacitors 27 of the energy storage elements 26 and 57 at the d.c. voltage consumer 2.

The inductances 10, additionally shown in the drawing, can be used for reducing the harmonics in the area of the a.c. voltage source 3, as already explained in detail with the aid of Fig. 1. In Figs. 7 to 11 is shown in detail the sequence of the control processes of the control device 29 shown in Fig. 6.

In all these diagrams the abscissa represents the time (t) and the ordinates represent the voltage (U). In Fig. 7 is now shown the output signal of the delta generator 68 with the aid of a diagram line 73. This diagram line 73 is provided with switching thresholds 74 and 75 which are fixed through the control amplifier 49 by presetting of the adjusting members 47 or the presetting of the actual value of the voltage at the junction 39. After determining the difference between these two values, the switching threshold 74 or 75 is displaced in the direction of the voltage. In the embodiment shown in Fig. 7 the switching device 24 is closed for example at the instant 76 and opened again at instant 77, whilst in the region of the negative halfwave of the diagram line of the delta generator 68 at instant 78 the switching device 56 is closed and opened again at instant 79. For example, if the control amplifier 49 detects a corresponding difference or if the control amplifier 70 supplies a corresponding differential signal to the comparators 64 and 66, this switching threshold 74 can be displaced from the position of the switching threshold 74 to the switching threshold 80, shown in double-dash lines, and the negative switching threshold 75 is displaced into the switching threshold 81 indicated by double-dash lines. From this follows that a time period 82 between an instant 83 and 84 which switches the switching device 24 or 56 on and off becomes larger than a time

period 85 between the instants 76 and 77. From this follows that the magnetic energy store 19 is charged longer and that during the subsequent discharge processes a greater energy can be discharged in a shorter period of time.

For the sake of clarity it is also pointed out that the diagram lines in Fig. 7 to 10 are shown synchronised in time. A diagram line 86 thus shows the switching state of the switching device 24, whilst a diagram line 87 shows the switching state of the switching device 56. Diagram lines 88 and 89 in Fig. 10 show proportional voltages at the switching devices 24, 56 in the intermediate circuit 6 in relation to the time period 82 and 85. The respective average voltages during the switching periods of the switching devices 24 and 56 are represented by the diagram lines 90 and 91.

Fig. 11 shows a control characteristic of the switching device 24 and 56. In this diagram a voltage U is represented both by the abscissa as well as the ordinate, the voltage represented by the ordinate in this case corresponds to the mean voltage of diagram line 90, 91 shown in Fig. 10, whilst the voltage of the switching threshold 74, 81 is represented by the abscissa. From this comparison can be seen that with different threshold values the cross-over points between voltage threshold value and mean value are situated on a straight line.

Fig. 12 shows an alternative embodiment of the voltage transformer 4 with a control amplifier 92 for producing a switching threshold 74, 75. The formation of a switching threshold 74, 75 is applied to the control amplifier 92 via a line 93 from the intermediate circuit 6 and via a line 94 from the adjusting member 47 shown for example in Fig. 5. The switching threshold resulting therefrom is applied to the output 95 of the control amplifier 92. Magnetic nergy stores 96 and switching devices 97, 98, 99 are arranged on

the a.c. voltage side, i.e. before the rectifier 5. The advantage of this embodiment of the voltage transformer 4 is the considerable reduction in the mains current harmonics. In this case, however, the magnetic energy store 96 and the switching devices 97 to 99 as well as the rectifier 5 should be three-phase in the first place.

It is furthermore evident that forward and reverse blocking voltages in this case appear at the rectifiers in both current flow directions and that the switching devices 97 to 99 are constructed as bidirectional bipolar elements, such as for example an appropriate combination of unidirectional bipolar power semiconductors 46, such as for example an antiparallel circuit of symmetrically blocking GTO thyristors, such as shown in the present embodiment.

The reference numerals already used in the aforedescribed figures are also used for those parts in this embodiment which correspond to those of the aforedescribed figure.

The power part of the voltage transformer 4 is formed by connecting together the magnetic energy store 96 on the input side, the switching devices 97 to 99, a diode bridge of the rectifier 5 on the output side and an electric energy storage element 100. For the complete control of the voltage transformer 4 the voltage in the intermediate circuit 6 must again be above the peak value of the rectified mains voltage. The switching states can be preset via the control of the switching devices 97 to 99, so that in switching state I the switching device 99 is open, i.e. the current flow is interrupted and the switching device 97 and 98 is closed, so that a current flow via the switching device 97, 98 is possible. In switching state II, on the other hand, the switching device 97 is open and the

switching devices 98 and 99 are closed, whilst in the switching state III the switching devices 98 are open and the switching devices 97 and 99 are closed. The switching state IV is a neutral state in which all switching devices 97 to 99 are open.

This circuit now makes it possible by means of pulse width modulation to provide a voltage converter system for the intermediate circuit voltage appearing at the a.c. voltage side of the rectifier 5 as a function of the current flow, which voltage converter system maintains the balance with the mains voltage system via series-connected magnetic energy stores 96 or inductances 101. These inductances 101 can be partly formed by the inner inductance of the non-ideal network or the leakage inductance of a transformer which may be connected in series with it. The output of the control apparatus 102 is matched to the power requirement of the d.c. voltage consumer 2 in accordance with the control voltage deviations in the intermediate circuit 6, which are fixed by the control amplifier 92. To prevent fundamental reactive power, through this control apparatus 102 it is possible to determine the difference of both voltage systems arranged orthogonally to the mains voltage and the current or power flow of the voltage transformer 4 can be directly changed on the input and output sides. The approximately sinusoidal mains currents are transferred to an intermediate current circuit, in accordance with the function of the diode bridge on the output side, of which the stationary mean value is equal to that of the mean value of the load current. The electric energy storage elements 100 boost the voltage in the intermediate circuit 6 which at a constant current load only has to take up the pulse frequency change in the intermediate current circuit.

For determining the control signals in the switching devices 97 to 99 f the voltage transformer 4, the standardized desired converter phase voltages, which ar

sinusoidal when in the stationary phase and are applied to the output of the control apparatus 102, are transformed via a comparison with a pulse-frequency delta voltage from a delta generator 68 by means of a comparator 103 into binary pulse width modulated phase switching signals or into the different switching states characterised by a "Tripler". As a result of the bivalence, at least two phase switching signals are each at the same level now, whereby each switching state can be produced via a short-circuit between the corresponding phases in accordance with the above-described switching states I to IV, or the controls to be associated with the rectifiers of the switching devices 97 to 99.

The control of the switching device 97 to 99 in a star connection takes place via a logic identity element 104 and an OR element 105 via the lines 106 shown in full lines.

The supply to the switching devices 97 to 99 in a delta connection takes place exclusively via the logic identity elements 104 of two phase switching signals, as shown by the connection of the switching devices 97 to 99 via the lines 107, shown in broken lines in the modified embodiment.

In the present embodiment of the voltage transformer 4, in each case two magnetic energy stores 96 are short-circuited at the same time, so that approximately sinusoidal currents are rectified by the rectifier 5. The mean value of the rectified current is equal to the mean value of the load current.

The control of the voltage in the intermediate circuit 6 takes place via the desired voltage of the intermediate circuit which in turn can be adjusted with the adjusting member 47 of the input device 30 described in Fig. 1 and as already described in detail with the aid of the embodiment shown in Fig. 1.

In Fig. 13 is shown another variation of the embodiment for the design of the switching devices 97 to 99 in which, in contrast to the parallel connection shown in Fig. 12, the anti-parallel connection of the symmetrically blocking GTO thyristors takes place in series.

According to the embodiment shown in Fig. 14, the switching devices 97 to 99 can be in the form of unipolar, bidirectional power semiconductors 46, for example insulated gate bipolar transistor (IGBT), but which can also be replaced by bipolar transistors, field effect transistors or the like.

In Fig. 15 is shown a vector diagram of the fundamental oscillations of the phase quantity for the voltage transformer 4 in Fig. 12.

This vector diagram shows that with a corresponding amplitude 108 and phase angle 109, a converter fundamental oscillation, i.e. the voltage via the electronic switching device 97 to 99 is supplied with a mains current fundamental oscillation 110 in phase with a mains voltage fundamental oscillation 111. This phase equilibrium can be maintained through a control output 112 by means of control apparatus 102.

In Fig. 16 an intermediate circuit voltage centre point, i.e. a neutral point 113 of the switching devices 97 to 99 and a neutral point 114 of the a.c. voltage source 3 are connected together, thus simplifying the control of the voltage transformer 4. The neutral point 114 of the a.c. voltage source 3 is thus formed by a neutral point 114 of additionally arranged capacitors 115 which form a mains filter 116.

In this case there must be provided three identical control device parts 117 for each phase of the a.c. voltag source 3, i.e. three control device parts 117 in the case of a

three-phase mains network. Since the arrangement and the operation of these control device parts 117 is identical for each of the three phases of the three-phase a.c. voltage source 3 shown, the control device part 117 is shown and described in detail only in connection with one of the three phases. The control with the control device part 117 in this case takes place in the form of a two-step current control.

In response to the control deviation of the voltage in the intermediate circuit 6, which is detected by the control amplifier 70, the detected control deviation is multiplied with the actual value of the mains phase voltage into a multiplier element 118 so that to its output 119 is applied in each case a desired value of the mains phase current which is proportional to the respective mains phase voltage. This approximately corresponds to the behaviour of the ohmic fundamental oscillations in the mains network. The control amplifier 70 and the multiplier element 118 form a double-loop control, i.e. a current controller with a superpositioned voltage controller.

If a difference between the desired positive mains phase current and the actual measured phase current exceeds the preselected switching threshold in the comparator stage 120, the switching device 99 and accordingly the switching devices 97, 98 controlled by the other control device parts 117, are switched through, whereby the mains voltage effects an increase in the actual value of the mains current. Falling below a lower switching threshold of the comparator stage 120 accordingly results in the opening of the switching device 99 or, when using power semiconductors, in a closing of the same or to a reduction in the phase current as a result of demagnetisation of the magnetic energy store 19 over the difference between intermediate circuit 6 and the mains voltage. This naturally also appli s to the other phases of the a.c.

voltage source 3. For complete control the voltage in the intermediate circuit 6 must therefore always be above the double peak value between two phases of the phase voltage of the a.c. voltage source 3.

The remaining parts which have not been described, which correspond to the parts of the embodiments in the previous examples, have again been provided with the reference numerals used earlier.

In Fig. 17 is shown a different embodiment variation of the voltage transformer 4. The characteristic of this voltage transformer 4 is the magnetic energy stores 19, arranged on the a.c. voltage side, which have a switching element 121, formed from power electronic parts on the d.c. voltage side and operating at high frequency in relation to the mains frequency, and a diode 122 arranged in the intermediate circuit 6 as well as the electric energy storage element 26. The voltage at the d.c consumer 2 is again above the peak value of the rectified mains voltage. If necessary, a mains filter 123 is provided for reducing the harmonic current load at the a.c. voltage source 3 or the mains.

When the switching device 121 conducts, i.e. in a short-circuited three-phase network, the approximately linear increase in the phase currents is determined by the series-connected magnetic energy stores 19 and the instantaneous values of the network phase current. Starting from the neutral state, the phase current values reached during the OFF period are therefore directly proportional to the instantaneous values of the phase voltage and the ON period. The demagnetisation of the magnetic energy stores 19 takes place via the diode 122 to the electrical energy storage element 26 by way of an approximately linear change in the current. If the switching device 121 is switched on again directly at the end of the complete demagnetisation

process of the magnetic energy store 19, delta phase currents are formed with lateral sinusoidally varying height, as explained in more detail with the aid of Fig. 18. The mains currents filtered by the main filter 123 are approximately sinusoidal in shape and exhibit only a slight phase difference from the respective centre point voltage.

The ON period of the switching device 121 defining the mains current amplitude or the power flow in the intermediate circuit 6 can now be directly utilised for controlling the voltage in the intermediate circuit 6 of the system. This is achieved as follows:

The setting of the switching state store 52 or the associated switching-on of the switching device 121 through an inverter 65 causes a sawtooth generator 124 to be activated. When the voltage slope reaches a value above the output signal of the control amplifier 70, which is made up of the intermediate circuit voltage control deviation and a load state of the series connected d.c. voltage consumer, detected via the line 55, the switching state memory 52 and the slope generator are reset by the comparator 41. The ON period of the switching device 121 is thus defined directly by the output of the control amplifier 70. The end of the demagnetisation of the magnetic energy store 19 which now follows is determined by a detector device 125 and leads to a renewed setting of the switching state memory 52. The detector device 125 determines the state of magnetisation of the energy store 19, e.g. by the polarity of the voltage appearing at the diode 122, in which the blocking voltage indicates that the demagnetisation has been finished.

Fig. 18 now shows the current and the mains voltage sequence of a phase in the line between the magnetic energy store 19 and the rectifier 5. A diagram line 126 in this case shows the sawtooth-like shape of the phase current

caused by the effect of the control device 29 and diagram line 127 shows the shape of the phase voltage appearing in the same area.

Fig. 19 is an embodiment variant of the circuit for the voltage transformer 4 described in Fig. 17, in particular a different embodiment of a switching device 128. The same reference numerals for the same parts used in other embodiments are also used in this embodiment.

The switching device 128 is made up of the combination of a unidirectional, unipolar power semiconductor 129 with a three-phase diode bridge 130 connected in series with it.

Fig. 20 shows a further embodiment variant of the voltage transformer 4. The circuit diagram corresponds essentially to the embodiment shown in Fig. 17. However, compared to the embodiment shown in Fig. 17 it varies by the fact that the blocking voltage requirement of the power semiconductor 129 is halved and the control of the voltage of the intermediate circuit capacitive voltage centre point 131 is included in the control of the voltage of the intermediate circuit 6. Otherwise, with regard to the arrangement of the magnetic energy store 19, the circuit shown corresponds to the embodiment shown in Fig. 17, whilst the arrangement of the electric energy storage elements 26 and the structure of the control device 29 corresponds to that of the embodiment shown in Fig. 3.

In order to provide symmetry for the capacitive intermediate circuit voltage centre point 131, separate switching state memories 52 are provided for the switching devices 24 and 56 formed by the power semiconductors 129. If the voltage in the energy storage elements 57 is greater than in the energy storage elements 26, through the control amplifier 132 monitoring the symmetrical split of the intermediate circuit voltage, the conducting period of the

switching device 24 is shortened and that of the switching device 56 is lengthened, resulting in a voltage equilibrium in the two energy storage elements 26, 57.

This results during the appearance of a centre point current for balancing the split voltages. The tapping of the reset signal of the sawtooth generator 124 in this case has to be effected via an OR element 133, i.e. an OR function of the outputs of the switching state memory 52.

Finally it must be pointed out that it is possible within the scope of the invention to selectively interchange individual circuit parts or groups of the embodiments described, so far as this is operationally possible on the basis of the circuits described. Individual parts or groups of parts of the circuits described, both of the control device 29 as well as the intermediate circuit 6 or the part of the voltage transformer 4 on the mains side, can of course form independent inventive solutions on their own.

CLAIMS

1. Voltage converter device for a d.c. voltage consumer supplied via a single or multi-phase a.c. voltage source including a voltage transformer arranged between the a.c. voltage source and the d.c. voltage consumer, a rectifier and an intermediate circuit for fixing the voltage at the d.c. voltage consumer, wherein the intermediate circuit is associated with a control device which is connected to external devices for adjusting or monitoring voltage and/or current at the input of the d.c. voltage consumer, and an output of the control device is applied to a control input of a switching device which is arranged between an electric energy storage element and a magnetic energy store, and the energy storage element and the magnetic energy store are provided between an output from the intermediate circuit and the a.c. voltage source, and at least the energy storage element or the magnetic energy store is arranged in the intermediate circuit.

2. Voltage converter device according to claim 1, wherein the intermediate circuit is arranged between the rectifier and the d.c. voltage consumer.

3. Voltage converter device according to claim 1 or 2, wherein the magnetic energy store and the energy storage element are arranged in the intermediate circuit.

4. Voltage converter device according to claim 2, wherein the switching device is connected in parallel with the energy storage element and these are arranged between the positive and negative potential of the intermediate circuit, in which a switching element is arranged in at least one supply line, applied to the positive potential, between the switching device and the energy storage element.

5. Voltage converter device according to claim 3, wherein the switching element is constructed as a diode in the supply line and is arranged in the flow direction to

the d.c. voltage consumer.

6. Voltage converter device according to claim 1 or 2, wherein two switching devices in a connecting line, connecting the positive and negative potential of the intermediate circuit, are connected in parallel with two series-connected energy storage elements arranged in a further connecting line and the two parallel-connected connecting lines between the two storage elements are connected to each other by means of an intermediate line.

7. Voltage converter device according to claim 6, wherein the control device alternately acts upon the control inputs or drives of the series-connected switching devices in order to switch through the switching devices, and between the junctions of the supply line applied to the negative potential of the rectifier and the parallel running connecting lines for the switching device and the energy storage elements as well as the junctions of the supply line applied to the positive potential of the rectifier, there are provided switching elements or diodes arranged in the flow direction.

8. Voltage converter device according to any preceding claim, wherein inductances are arranged between the rectifier and the a.c. voltage source.

9. Voltage converter device according to claim 1, wherein in the connecting line an electric energy storage element is connected in the supply line between positive and negative potential of the rectifier and inductances are arranged between the rectifier and the a.c. voltage source and switching devices associated therewith are arranged between the inductances and the rectifier.

10. Voltage converter device according to claim 9, wherein in a three-phase a.c. voltage source the switching devices are arranged in star connection.

11. Voltage converter device according to claim 9, wherein in a three-phase a.c. voltage source the switching devices are arranged in delta connection.

12. Voltage converter device according to any preceding claim, wherein the control device for activating the control input(s) or drive(s) of the switching device(s) is developed for pulse width modulation.

13. Voltage converter device according to any one of claims 8 to 12, wherein an electric energy storage element, such as a capacitor, is connected in parallel with the d.c. voltage consumer and an operating voltage from this electric energy storage element, depending on the value of the inductance and the closure period of the switching devices effected by the control device via the drive of the switching devices, is less than an operating voltage of the magnetic energy store arranged between the switching devices and the a.c. voltage source.

14. Voltage converter device according to any preceding claim, wherein the or each switching device is in the form of a bipolar or bidirectional power semiconductor, such as a Triac thyristor.

15. Voltage converter device according to any preceding claim, wherein the or each switching device is in the form of a power semiconductor which can be switched off, such as a transistor, insulated gate bipolar transistor, or field effect transistor.

16. Voltage converter device according to any one of claims 1 to 13, wherein the or each switching device is in the form of a mechanical switch, e.g. relay, contactor or the like.

17. Voltage converter device according to any preceding claim, wherein the switching device has arranged in the feed line of two series-connected diodes of the rectifier a voltage-controlled transistor, e.g. an isolated gate bipolar transistor and two diodes, connected in parallel with this, arranged counter to the flow direction of the diodes of the rectifier, and a junction for connecting the phase of the a.c. voltage source is arranged between the two diodes connected in parallel with the two voltage-

controlled transistors.

18. Method for supplying a d.c. voltage consumer with a constant, preadjustable voltage from an a.c. voltage source, in which the a.c. voltage is rectified and the d.c. voltage is kept at a preadjusted value in an intermediate circuit, wherein the intermediate circuit is applied to the a.c. voltage source at timed intervals in successive periods of varying time and between these periods the energy supplied from the a.c. voltage source is stored in an energy storage element or an inductance, and during the period the energy taken up by the inductance or the energy storage element, charged from supply voltage of the a.c. voltage source, is supplied as the operating voltage to the d.c. voltage consumer.

19. Method according to claim 18, wherein the a.c. voltage source is applied exclusively to a magnetic energy store in the intermediate circuit, and during the period the magnetic energy store is connected to the energy storage element arranged between said energy store and the d.c. voltage consumer, and the operating voltage of the energy storage element in the intermediate circuit is fixed above the switching time of a switching device connected in parallel therewith.

20. Method according to claim 18 or 19, wherein the energy supplied by the a.c. voltage source is stored and is connected to and discharged from energy storage elements with magnetic energy stores arranged in the intermediate circuit at periods of adjustable time spaced at timed intervals from each other and the operating voltage applied to the d.c. voltage consumer is less than the operating voltage of the energy storage elements between the a.c. voltage source and the switching device, and the voltage level at the d.c. voltage consumer is variable by the switching time of the switching device.

21. Method according to any preceding claim, wherein the inductance is charged up via a switching device at

periods of preadjustable times spaced apart at timed intervals and is applied during the periods via the rectifier to the intermediate circuit or its electric energy storage elements, and the time length between the periods or the time length of the period is chosen in such a way that the operating voltage in the d.c. voltage consumer is different from the operating voltage in the a.c. voltage source.

22. Voltage converter device for a d.c. voltage consumer substantially as herein described with reference to Figures 1 to 4 or Figure 5 or Figures 6 to 11 or Figure 12 or Figure 13 or Figures 14 and 15 or Figure 16 or Figures 17 and 18 or Figure 19 or Figure 20.

23. Method for supplying a d.c. voltage consumer substantially as herein described with reference to Figures 1 to 4 or Figure 5 or Figures 6 to 11 or Figure 12 or Figure 13 or Figures 14 and 15 or Figure 16 or Figures 17 and 18 or Figure 19 or Figure 20.

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Relevant Technical fields

(i) UK Cl (Edition K) H2F (FXS FXT FXX FMX FMDRS FMDRT FMDRX)
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(ii) Int Cl (Edition)

Databases (see over)

(i) UK Patent Office

(ii)

Search Examiner

B J EDE

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Documents considered relevant following a search in respect of claims 1-17 AND 22

Category (see over)	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2219877 A	(MAGNE TEK) see D1, L1, L2, Q1, D2, C5	1
X	GB 2213614 A	(FARNELL INSTRUMENTS) see 3, 11, 12, 14 and 6 Figures 3 and 4	1
X	GB 2079083 A	(THOMSON-BRANDT) see R, L, T1, D1, C2 Figures 1 and 3	1
X	GB 0949081 A	(MARCONI) see page 1 lines 18-30 and Figures 1-3	1
X	EP 0199903 A2	(HITACHI) see 20, 31, 33, 34, 40 Figure 1	1

Category	Identity of document and relevant passages	Relevant to claim(s)

Categories of documents

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